A 100-KILOWATT X-BAND FERRITE-DIODE LIMITER

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In the last few years, significant progress has been made in the development of improved transmitting-receiving (TR) devices that provide increased reliability in comparison with gas-discharge TR tubes. For example, an all-ferrite TR device consisting of a high-power limiter and three fast-switching circulators is finding increasing application in modern airborne weather radars.[1] This paper describes still another advance in the area of TR devices: a newly-developed, all-solid-state, passive limiter.

The limiter illustrated in Fig. 1 consists of a high-power ferrite stage, followed by a lower-power diode stage. The performance of this X-band limiter is as follows: peak-power is 100 kilowatts, average power is 100 watts, maximum flat-leakage is 18 milliwatts, spike-energy is 0.1 erg, low-level insertion loss is 1.3 dB, and bandwidth is 5 percent. The most significant advance in this limiter is the achievement of high power in conjunction with relatively low insertion loss; power levels reported previously for all-solid-state passive X-band limiters were in the range of 10 kilowatts.[2-4]

THE FERRITE LIMITER

The ferrite stage is a parallel-pumped, subsidiary-resonance, reciprocal limiter. Fig. 2 shows a simplified cross-sectional view of this device. As shown in the illustration, the ferrite element entirely fills a reduced cross-section rectangular waveguide. In this configuration, rf impedance is matched to WR-90 waveguide by use of quarter-wave, reduced-height waveguide sections and matching posts. The elongated surfaces of the ferrite element are metallized and soldered to the waveguide fixture. This technique provides low insertion loss and high average-power capacity. The dc magnetic biasing field (H_{dc}) is applied parallel to the broad walls of the waveguide, as shown in Fig. 2. This parallel pumping represents a new approach; ferrite limiters reported to date have employed primarily perpendicular pumping. Parallel pumping was selected because it provides a high figure of merit, defined as the ratio of high-level limiting to

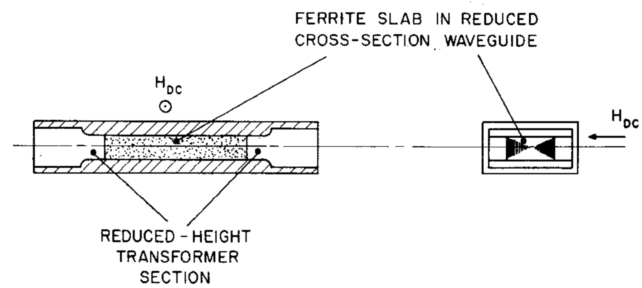

Fig. 2— A simplified cross-sectional view of the ferrite stage.

small-signal insertion loss, in conjunction with high peak and average rf power capacities. A typical figure of merit is in the range of 100; however, under laboratory conditions, parallel-pumped limiters having figures of merit in the range of 150 have been constructed.

Fig. 3 shows the high-level performance of the parallel-pumped limiter. The threshold power for flat leakage is 50 watts. The limiting at an input of 100 kilowatts is 30 dB, corresponding to a flat leakage of 100 watts. Also shown in Fig. 3 is the amplitude of the leading-edge spike as a function of input power. At an input of 100 kilowatts, the spike amplitude is 32 kilowatts, corresponding to a spike suppression of 5.1 dB. The low-level insertion loss is 0.40 dB, and the bandwidth is 5 percent. The flat and spike leakages from the ferrite limiter are at levels that are sufficiently low to be handled by the two-stage, microwave-diode limiter.

THE MICROWAVE-DIODE LIMITER

Fig. 4 shows a simplified cross-sectional view of the microwave-diode limiter. This limiter consists of two stages that employ loop-coupled point-contact diodes for fast driving of the limiter diodes into conduction at high power levels. The first stage employs a relatively high reverse-breakdown-voltage PIN diode that is used primarily for reduction of the hundred-watt flat leakage from the ferrite limiter. In addition,

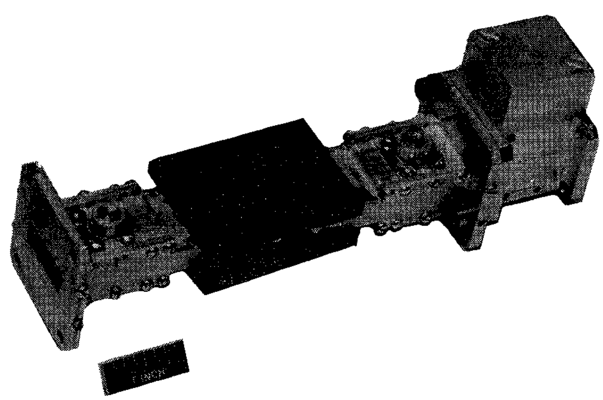

Fig. 1— Photograph of the newly-developed, all-solid-state, passive limiter.

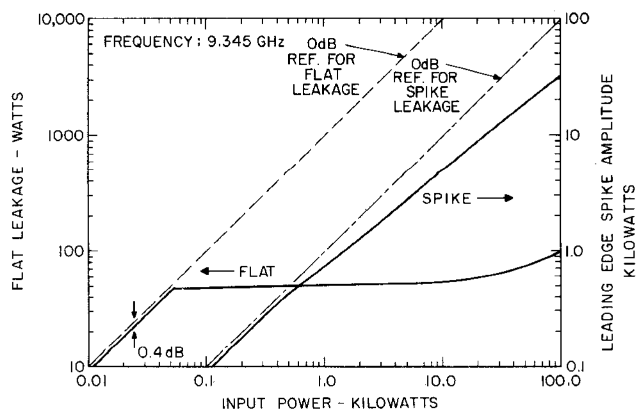

Fig. 3— High-level performance of the parallel-pumped limiter.

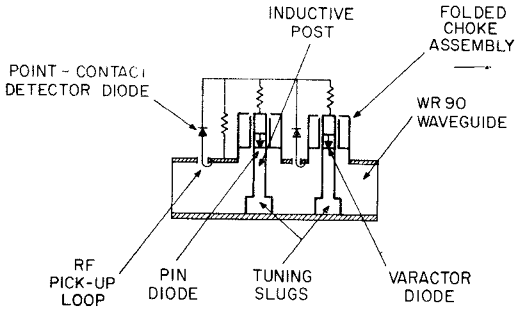

Fig. 4— A simplified cross-sectional view of the microwave-diode limiter.

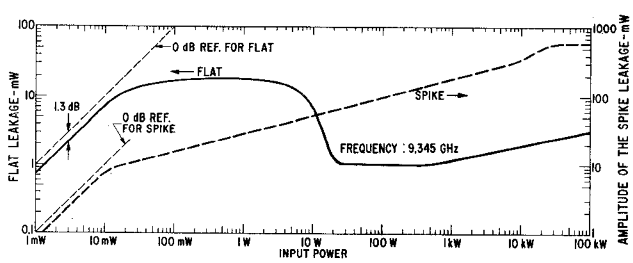

Fig. 5— RF leakage for the combined ferrite-microwave-diode limiters as a function of rf input power.

the p-n junction varactor diode provides the lowest level of limiting. Thus, both stages are instrumental in suppression of the spike and flat leakages passed by the ferrite limiter.

A flexible assembly, illustrated in Fig. 4, that permits adjustment of several electrical parameters was constructed to optimize the performance of the two-stage diode limiter at 9.345 GHz. In this construction, optimization involved proper locations for the diodes in the choke assemblies, adjustments of the tuning slugs, positioning of sliding elements in the choke assemblies, and proper penetration of the coupling loops into the waveguide. The small-signal insertion loss of the two-stage microwave-diode limiter was 0.9 dB, and the bandwidth was 5 percent.

PERFORMANCE OF COMPLETE LIMITER ASSEMBLY

Fig. 5 shows the rf leakage for the combined ferrite-microwave-diode limiters as a function of rf input power. These results are from the tests performed at a pulse length of 5.5 microseconds and a duty cycle of 0.001. As shown in the illustration, the small-signal insertion loss of the complete assembly was 1.3 dB. The threshold level was approximately 10 milliwatts, and the maximum flat leakage was 18 milliwatts for all power levels up to 100 kilowatts. At an input of 100 watts the flat leakage was 1 milliwatt, and, at 100 kilowatts, the flat leakage was 3 milliwatts, corresponding to 75 dB of flat limiting.

Fig. 5 also shows the amplitude of the leading-edge spike. At 100 kilowatts, this amplitude was 600 milliwatts. The width of the spike at the 3-dB level was 10 nanoseconds; the spike energy contained above the level of the flat leakage was approximately 0.1 erg.

CONCLUSIONS

A 100 kilowatt, X-band, passive, ferrite, microwave-diode limiter has been developed that provides 75 dB of limiting, passes a spike energy of 0.1 erg, has a small-signal insertion loss of 1.3 dB, and a bandwidth of 5 percent. This limiter represents a tenfold increase of peak-power capacity over X-band passive limiters reported to date. The new limiter also offers a significant improvement of reliability over the existing TR devices.

Table I

PERFORMANCE OF THE X-BAND FERRITE-DIODE LIMITER

Peak Power	100 kW
Average Power	100 W
Flat Leakage	18 mW maximum
Spike Energy	0.1 erg
Low-level Insertion Loss	1.3 dB
Bandwidth	5%

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